Development of 2AoA Chamber and Test System Facilitating 5G NR mmWave Mobile Rollout

Hiroaki Iida, Hideyuki Endo, Koichi Sunaga, Tomonori Morita, Tomohiro Kondo

[Summary] The worldwide rollout of 5G New Radio (NR) services is driving increased demand for evaluation of user equipment using mmWave technology to assure a wider communications bandwidth as well as development of new standards for RF conformance tests. Until now, the main performance tests have focused on signal angle of arrival (AoA) from the base station but recent standards for assuring high network mobility now define tests for evaluating performance with two signals arriving simultaneously (2AoA) from a base station. These mmWave tests incur high test-equipment costs and require large equipment installation space. To solve this issue, we have developed a lower-cost system platform supporting new 2AoA and conventional 1AoA tests. This article introduces a new radio anechoic chamber developed for by this platform as well as the platform features.

1 Introduction

Rollout of 5G New Radio (NR) is starting in various countries due to increases in data traffic and the need for faster data rates. The NR technology uses both Frequency Range 1 (FR1) at by earlier mobile communications at the 6-GHz max, and Frequency Range 2 (FR2) at 24.25 GHz and above supporting a wider communications bandwidth. Although FR1 is the current mainstream technology, if FR2 is expected to enter future widespread use[1)].

Since the 3rd Generation Partnership Project (3GPP) TS 38.521-2 NR; User Equipment (UE) conformance specification; Radio transmission and reception; and Part 2: Range 2 standalone[4)] standards for testing the RF characteristics of FR2 UE specify use of Over-The-Air (OTA) measurements, future testing will implement the Direct Far Field (DFF) and Indirect Far Field (IFF) technologies for positioning the UE in the OTA chamber, which will greatly increase infrastructure costs and equipment space requirements.

The 3GPP TS 38.533 NR User Equipment (UE) conformance specification Radio Resource Management (RRM)[2)] specification for testing FR2 UE mobility performance targets essential functions for measuring Rx performance on which handover (movement between base stations) depends.

The FR2 RRM test not only specifies various test scenarios related to the base station angle of arrival (AoA) but also adds simulated 2AoA tests requiring a function simulating AoA differences of 30°n 60°, 90°, 120°, and 150°. Consequently, 2AoA testing requires higher setup costs and more equipment space than current 1AoA tests.

This article introduces a lower-cost, space-saving OTA chamber for both conventional 1AoA tests (RF, Demodulation, and RRM) and 2AoA tests (RRM) as well as the features of the RF Conformance Test System ME7873NR incorporating the above chamber.

2 Chamber Development Concept

Development targeted the following two concepts to meet the 3GPP test system requirements.

2.1 Cost Reduction using Single Product Configuration

As shown in Figure 1, the space in the OTA chamber where the spherical wave output from the antenna propagates can be considered equivalent to the 3GPP Quiet Zone (QZ). Additionally, the amplitude dispersion in the QZ is called the Quality of Quiet Zone (QoQZ). Our development concept was to implement a lower-cost and space-saving OTA chamber facilitating the QZ size and D size (UE antenna size) tests required by Power Class (PC) 3 UE, as well as to satisfy QoQZ requirements for both 1AoA tests (RF, Demodulation, and RRM) and 2AoA tests (RRM). Additionally, this implementation supports the DFF technology as shown in Figure 1. This CATR (Compact Antenna Test Range) design was achieved using IFF technology to convert the spherical wave to a planar wave using a reflector.

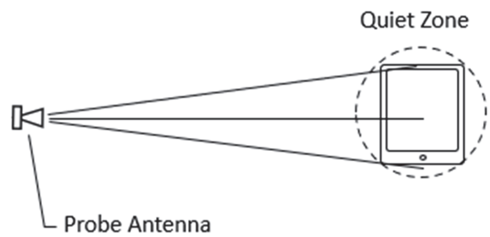

Figure 1 Quiet Zone

2.2 Extending Current Hardware

The second concept was to be possible to upgrade from CATR Chamber MA8172A configuration supporting 1AoA testing by using existing components as much.

3 Key Design Points

This section introduces the following two key hardware design points.

3.1 Smaller Chamber Size using Hybrid Method

There are three approved methods for implementing 2AoA RRM tests: 1. DFF only, 2. IFF only using multiple reflectors, and 3. Hybrid method combining both DFF and IFF methods. Each method has a specific Measurement Uncertainty as well as advantages and disadvantages, such as cost of introduction. We selected the Hybrid method due to lower introduction costs assuming RF test Measurement Uncertainty requirements are satisfied. This new MA8172B supports both the IFF technology at the 0° position and the DFF technology at the 30°, 60°, 90°, 120°, and 150° positions. The predecessor MA8172A used the IFF technology for 1AoA tests while the MA8172B configuration extends the MA8172A functionality to include the DFF technology as shown in Figure 2 and is designed for easy compatibility with the existing FR2 RF Conformance Test System ME7873NR.

Using DFF technology DFF, the DFF antenna must be about 110 cm from the QZ center when the D size is 5 cm, the QZ size is 40 cm and the frequency is 52.6 GHz. Separating the virtual antenna positions at 30°, 60°, 90°, 120°, and 150° from the QZ requires a one-size bigger chamber than in Figure 3. Obviously, a smaller chamber size is preferable from the viewpoints of equipment space and introduction costs. Consequently, the MA8172B design uses an antenna and mirror configuration (Figure 4) to reflect the beam using a planar mirror from the DFF antenna positioned below. This configuration (Figure 4) resulted in a relatively smaller chamber compared to the design using virtual antenna positions (Figure 3).

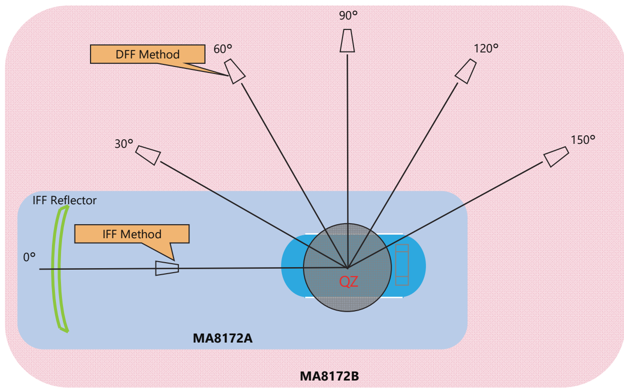

Figure 2 MA8172A and MA8172B Configuration

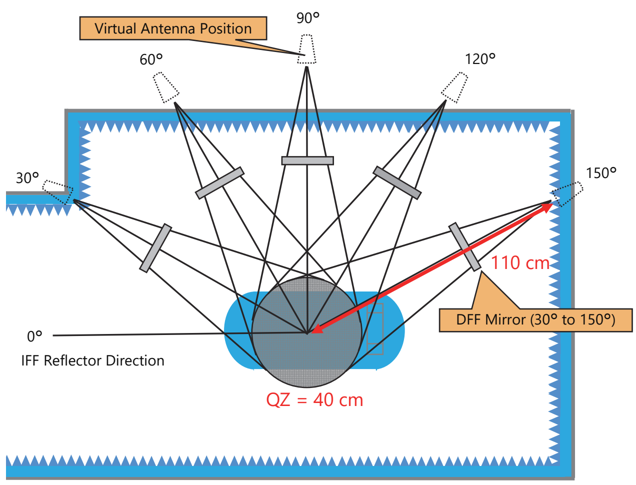

Figure 3 Chamber and Virtual Antenna Positions

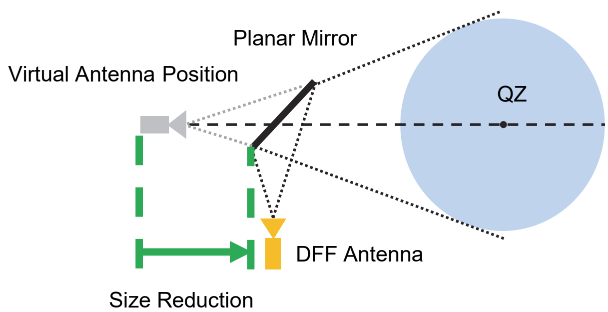

Figure 4 Planar Mirror and DFF Antenna Layout

3.2 Determining Antenna Design Method

Two methods were considered to implement the configuration combining an antenna and mirror described in section 3.1: (i) fixing five antennas the AoA positions; (ii) moving one antenna to each of the five AoA positions. To flexibly support other non-3GPP tests, the MA8172B design adopted method (ii) facilitating any AoA setting not specified by 3GPP.

Figure 5 shows the essential points of the fixed multiple antenna and movable single antenna designs. Since the fixed method is configured using one Remote Radio Head (RRH) shared by a group of five antennas, the signals must be split using dividers and RF cables. In addition, amplifier modules are required to compensate for the drop in signal power between the RRH and antennas, which greatly increases the number of peripheral devices in comparison to the smaller device count required by the movable method. The larger number of FR2 devices required by the fixed method is expensive while the movable method has fewer FR2 devices and a test system can be configured at lower cost using commercial motors to drive the positioner.

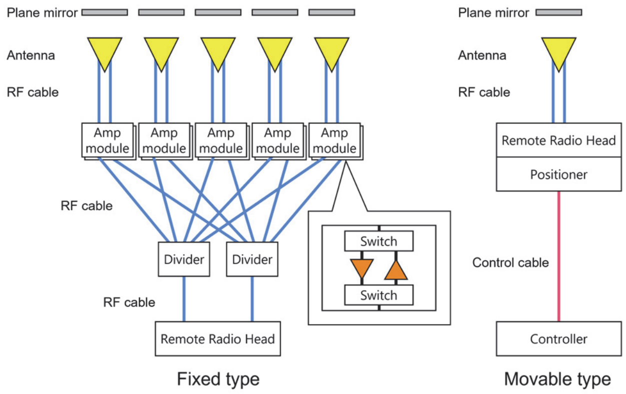

Figure 5 Fixed and Movable Structural Components

Figure 6 outlines the movable antenna. It uses a positioner on a circular rail running around the central QZ and is composed of a set of the DFF antenna, planar mirror, and RRH driven by a motor from between 30° and 150° facing the IFF reflector (AoA #1). The movable design must consider the time to move to the measurement position as well as aging deterioration of the moving parts. Although 30° of movement requires several seconds, the measurement time at each position is sufficiently longer than the movement time so as not to cause operational problems. Additionally, wear damage to cables bending and moving repeatedly (mostly IF cable connecting test station and RRH and control cable) is minimized using cable carrier.

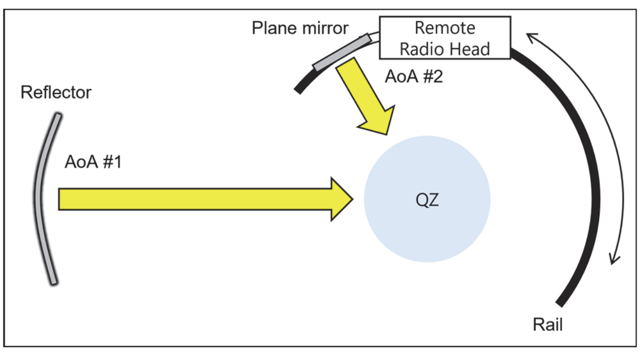

Figure 6 Outline of Movable Antenna

4 Product Introduction

4.1 ME7873NR

Anritsu's 3GPP-compliant New Radio RF Conformance Test System ME7873NR test platform is certified by the GCF (Global Certification Forum) and PTCRB (PCS Type Certification Review Board) and supports the main 3GPP frequency bands including FR1 and FR2.

The easy-to-use test interface supports successive RF, Demodulation, and RRM tests. To execute required tests efficiently, software sequences to run tests and output measured result pass/fail reports are created easily by selecting test cases from the task pane at the screen center and clicking [Insert] as shown in Figure 7.

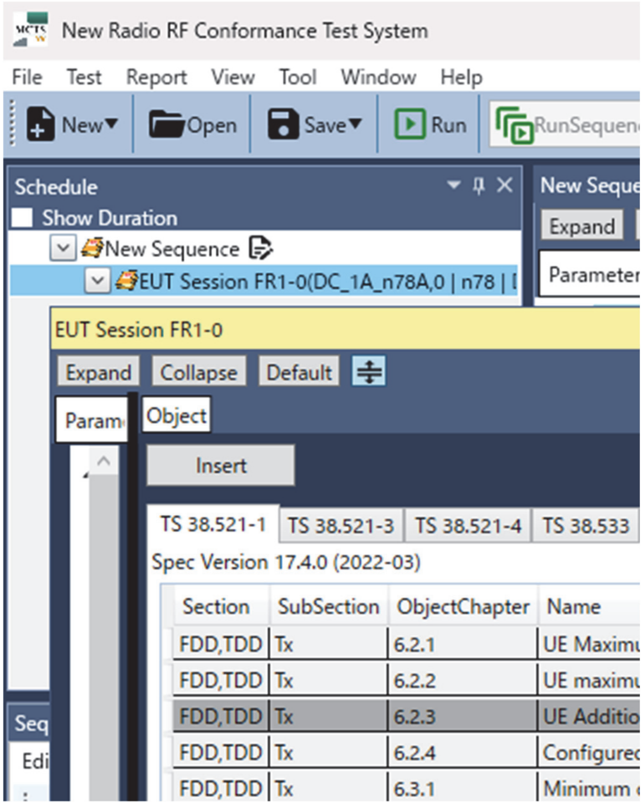

Figure 7 Test Sequence Creation Screen

ME7873NR MA8172B (Figure 8) has designed to have common configuration on the left side with MA8172A, MA8172A can support 2AoA RRM test with substituting the left side of its configuration, therefore.

Figure 8 ME7873NR FR2 System (MA8172B Configuration)

4.2 Introduction to 2AoA RRM Test Case (TC) Implementation (TS38.533 5.6.1.1)

The 3GPP TS 38.533[2)] specification defines several 2AoA RRM test cases. This section outlines the EN-DC FR2 event-triggered reporting without gap in non-DRX test (called TC 5.6.1.1 for simplicity hereafter) defined in 3GPP TS 38.533 section 5.6.1.1 and explains analysis of the measured results using the ME7873NR.

4.2.1 Test Objectives

TC 5.6.1.1 evaluates the adjacent Cell detection time as an index of the UE adjacent[1] FR2 NR Cell measurement performance. It establishes the EN-DC (E-UTRA NR Dual Connectivity) state using a LTE Cell or FR2 NR Cell, and tests whether the UE can detect the adjacent FRS NR Cell coming from another direction within the specified time.

4.2.2 Test Configuration and Procedure

This section explains the TC 5.6.1.1 test configuration, measurement procedure and performance requirements. The cells are configured using a LTE cell as the EN-DC PCell (Primary Cell) and an FR2 NR cell as the EN-DC PSCell (Primary SCell) with a third adjacent FR2 NR cell in the same frequency band as the PSCell. T1 and T2 define the measurement sections and after establishing EN-DC, the RMC (Reference Measurement Channel)[2] and the PSCell DL arrival direction are initialized before transitioning to the measurement section. Figure 9 shows the RRC layer message signaling series at the T1 and T2 sections. The RRC (Radio Resource Control) Connection Reconfiguration[3] message is sent via the LTE cell in the T1 section and adjacent cell measurement is directed by the UE. The adjacent cell DL output is started in the T2 section. After meeting the Event A3[4] conditions in the preset Measurement report[5], the UE detecting the adjacent cell saves the Measurement report in the UL information transfer MR-DC[6] message and notifies the LTE cell. Elapsed time until Measurement report being received in the LTE cell from beginning of T2 is defined as the Measurement reporting delay and is stated as a test criterion in TC 5.6.1.1.

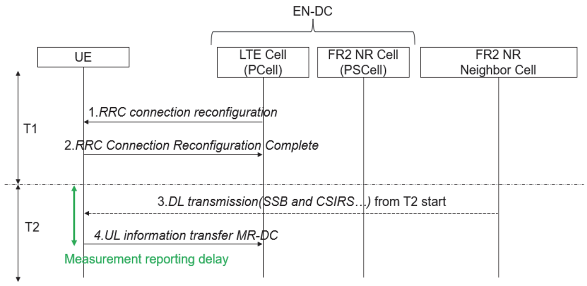

Figure 9 TC 5.6.1.1 Test Sequence

General RRM testing evaluates multiple test results statistically to evaluate whether the performance requirements are met. This test is also based on such statistical evaluation techniques, considering the measurement period between T1 and T2 is as 1 round, physical ID (PCID)[7] of the adjacent cell and DL arrival direction shall be updated every round, and then repeat to run round under condition as similar as that UE is in new adjacent Cell every time. At least repeat it 33 times need to make it to pass this test.

4.2.3 TC 5.6.1.1 Performance Requirements

Depending on the TS38.533[2)] 5.6.1.0 Minimum conformance requirements, the SSB based intra frequency cell required detection time condition is defined as the sum of the frame synchronization time required by PSS/SSS and the

---

1 Refers to any spatially close cell other than NR cell communicating with UE. Same meaning as "neighbor cell" in TS38.533[2)].

2 DL/UL schedule setting.

3 General-purpose message for resetting LTE RRC layer. For EN-DC, can also save the nr-SecondaryCellGroupConfig message for resetting UE NR RRC in this message; The adjacent cell measurement instruction in 5.6.1.1 are the settings for the UE-side NR RRC and use nr-SecondaryCellGroupConfig.

4 Parameter used for setting event-driven type network reporting Measurement Report Event A3 is threshold for RSRP difference between PSCell and adjacent NR Cell. Designed so T2 DL setting in 5.6.1.1 satisfies Event A3.

5 NR RRC message for reporting detected cell information, etc., to network side.

6 At EN-DC, used when transferring NR RRC-related signaling (NR RRC Measurement report, etc.) to PSCell NR RRC via LTE PCell.

7 Cell identifier in physical layer.

SSB signal measurement time. Although it changes according to test conditions, the typical parameters are as follows:

- C-DRX (Connected-Discontinuous Reception)[8] setting
- Adjacent cell frequency location (position) and Measurement Gap setting[9]
- SMTC (SS/PBCH block Measurement Timing Configuration) period[10]
- Whether adjacent cell is FR2[11]

TC 5.6.1.1 calculates the detection time condition as 1440 ms. In addition to this adjacent cell detection time, the communication delay required to send the Measurement report is assumed to be 2 ms. In other words, the total of 1442 ms is the required TC Measurement Reporting delay performance that the UE should satisfy.

4.2.4 Determining 2AoA Arrival Angle

The AoA setup[2)] referenced by TC 5.6.1.1 is Setup3. For a PC3 UE, in addition to 2AoA satisfying any of 30°, 60°, 90°, 120°, and 150° angles from any direction satisfying the EIS Spherical Coverage, the combination of the arrival angle and arrival angle difference must satisfy the different conditions for each trial. The ME7873NR platform with MA8172B chamber implements 2AoA by using the DFF for AoA as well as a driven positioner.

4.2.5 Software Implementation and Test Result Examples

The ME7873NR software for automating measurement uses the same GUI as the FR1 and FR2 test cases to execute TC 5.6.1.1 2AoA RRM test cases and confirm measurement results. Figure 10 shows an example of a TC 5.6.1.1 measurement result report listing each test parameter and corresponding result.

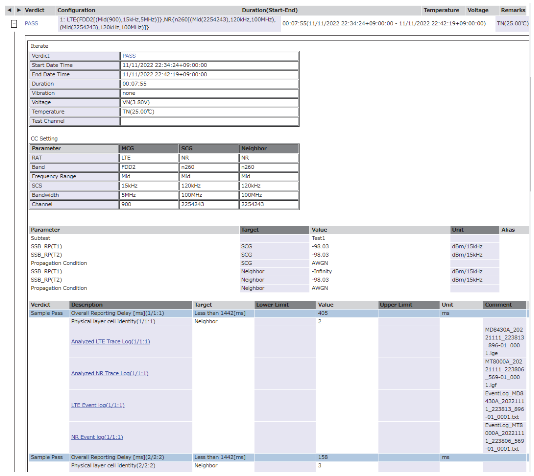

Figure 10 TC 5.6.1.1 Test Report (Extract)

A Cell – UE signaling log is also appended for each test Measurement report for detailed analysis and troubleshooting if a Measurement report is not received or when performance requirements are not satisfied. As an example of the signaling log, Figure 11 shows part of the T1 and T2 signaling logs, as well as the UL information transfer MR-DC message decode results. The Measurement Report in the decoded results message tree reports the measurement results for PCID=2 adjacent NR Cell.

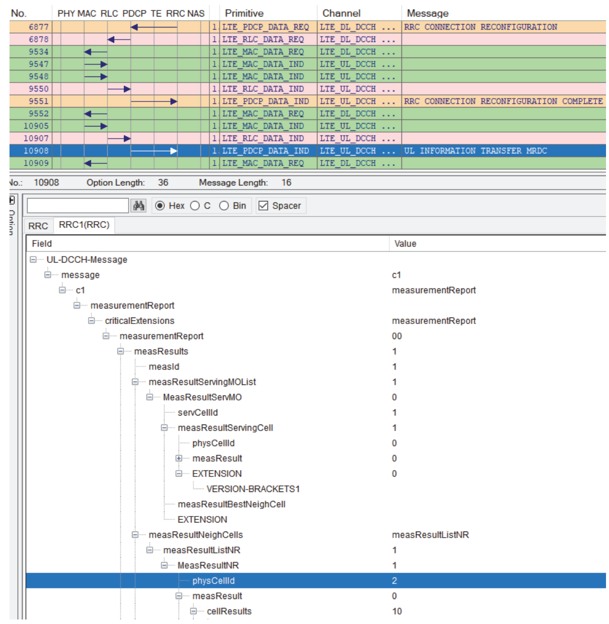

Figure 11 TC 5.6.1.1 Test Signaling Log (Extract)

8 Composition for intermittent TRx to cut power consumption. Required detection time depends on this DRX period.

9 When the measurement frequency is different from the PSCell frequency, for general UE implementations, RF tuning adjacent cell tests are performed only for the section specified by Measurement Gap. The required detection time depends on this Measurement Gap period.

10 The detection time depends on this period because the UE only executes adjacent SSB searches principally for the SMTC period section.

11 The FR2 measurement time increases due mostly to the Rx beam sweeping.

5 Conclusion

This article describes the features of the OTA Chamber MA8172B supporting both conventional FR2 UE performance tests (RF, Demodulation, and RRM) as well as 2AoA tests (RRM). It also introduces an example of a 2AoA RRM test case using the MA8172B in the NR RF Conformance Test System ME7873NR.

As a result of this development, the ME7873NR platform can evaluate 2AoA performance and facilitates RRM tests required to assure FR2 UE mobility.

By developing systems to test future advanced UE, Anritsu continues to support deployment of 5G NR.

References

1) Hiroyuki Baba, Osamu Yamashita, Hiroaki Iida, Masafumi Setsu. “Trends in 5G NR mmWave UE RF Conformance Test Standards”, Anritsu Technical Review No.30 (Sep. 2022)
2) 3GPP TS 38.533 v17.3.1(2022-07), “NR User Equipment (UE) conformance specification Radio Resource Management (RRM)”
3) 3GPP TR 38.810 v16.6.1(2020-11), “NR Study on test methods”
4) 3GPP TS 38.521-2 v16.12.0(2022-07), “NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 2: Range 2 standalone”

Authors

Hiroaki Iida
1st Product Development Dept.
Product Development
Mobile Solutions Division
Test & Measurement Company

Hideyuki Endo
2nd Product Development Dept.
Product Development
Mobile Solutions Division
Test & Measurement Company

Koichi Sunaga
1st Product Development Dept.
Product Development
Mobile Solutions Division
Test & Measurement Company

Tomonori Morita
2nd Product Development Dept.
Product Development
Mobile Solutions Division
Test & Measurement Company

Tomohiro Kondo
1st Product Development Dept.
Product Development
Mobile Solutions Division
Test & Measurement Company